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(54) Infrared spectrometer

(57) An infrared spectrometer, with which it is possible to investigate a sample, selectively or simultaneously, by transmission or reflection, comprises optical means for generating a beam (10) and focussing it (13) in a plane (17) for receiving the sample to be investigated, a detector arrangement as (24) or (28) situated for receiving rays transmitted through the sample and a second detector arrangement (31) for receiving light reflected by the sample on the same side of the plane as the beam generating means. Means (13) may be a parabolic mirror and the reflected rays may be collinated by a parabolic mirror (14). Mirrors (13) and (14) may be replaced by a common extra-axial paraboloid mirror (15).

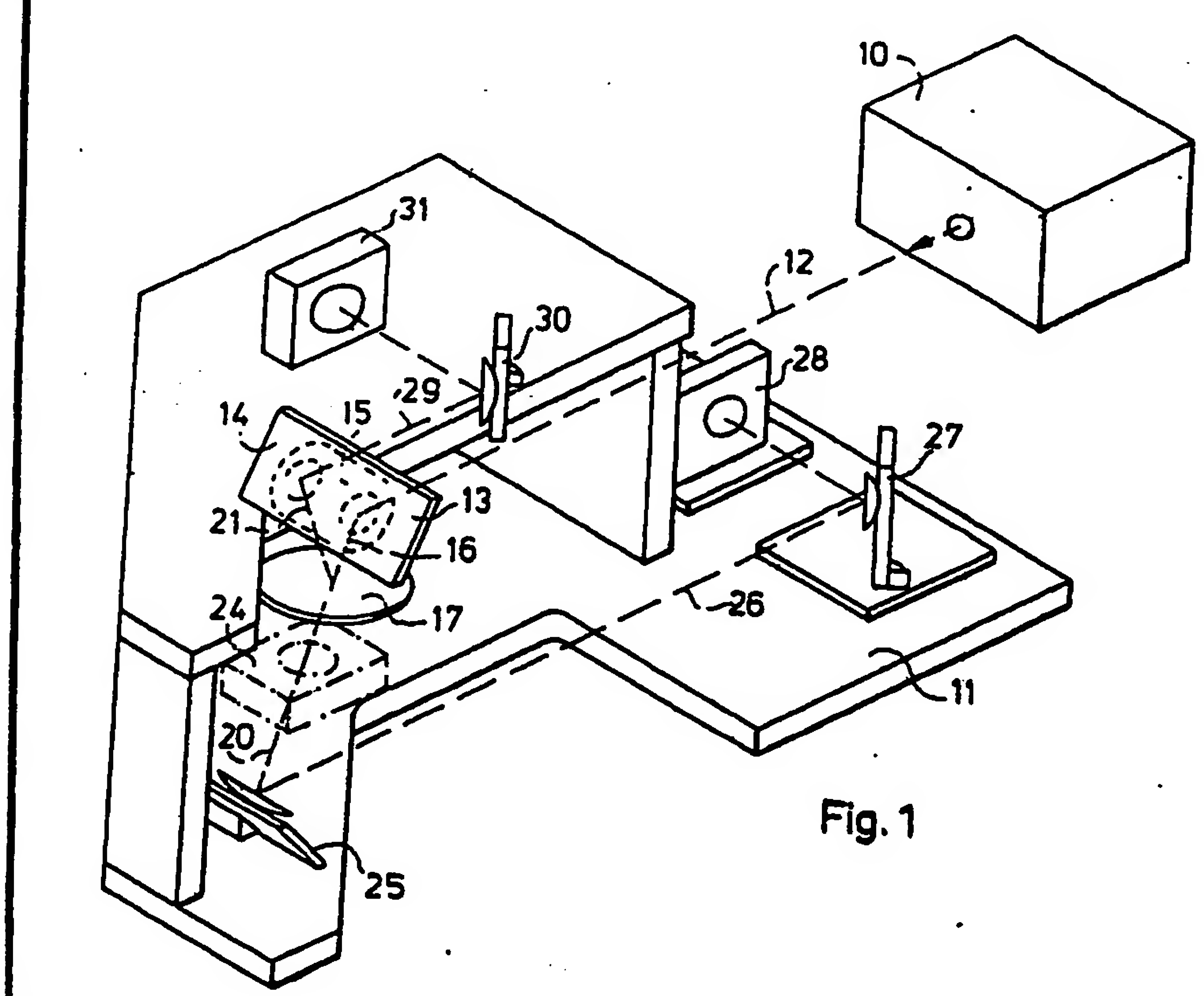

Fig. 1

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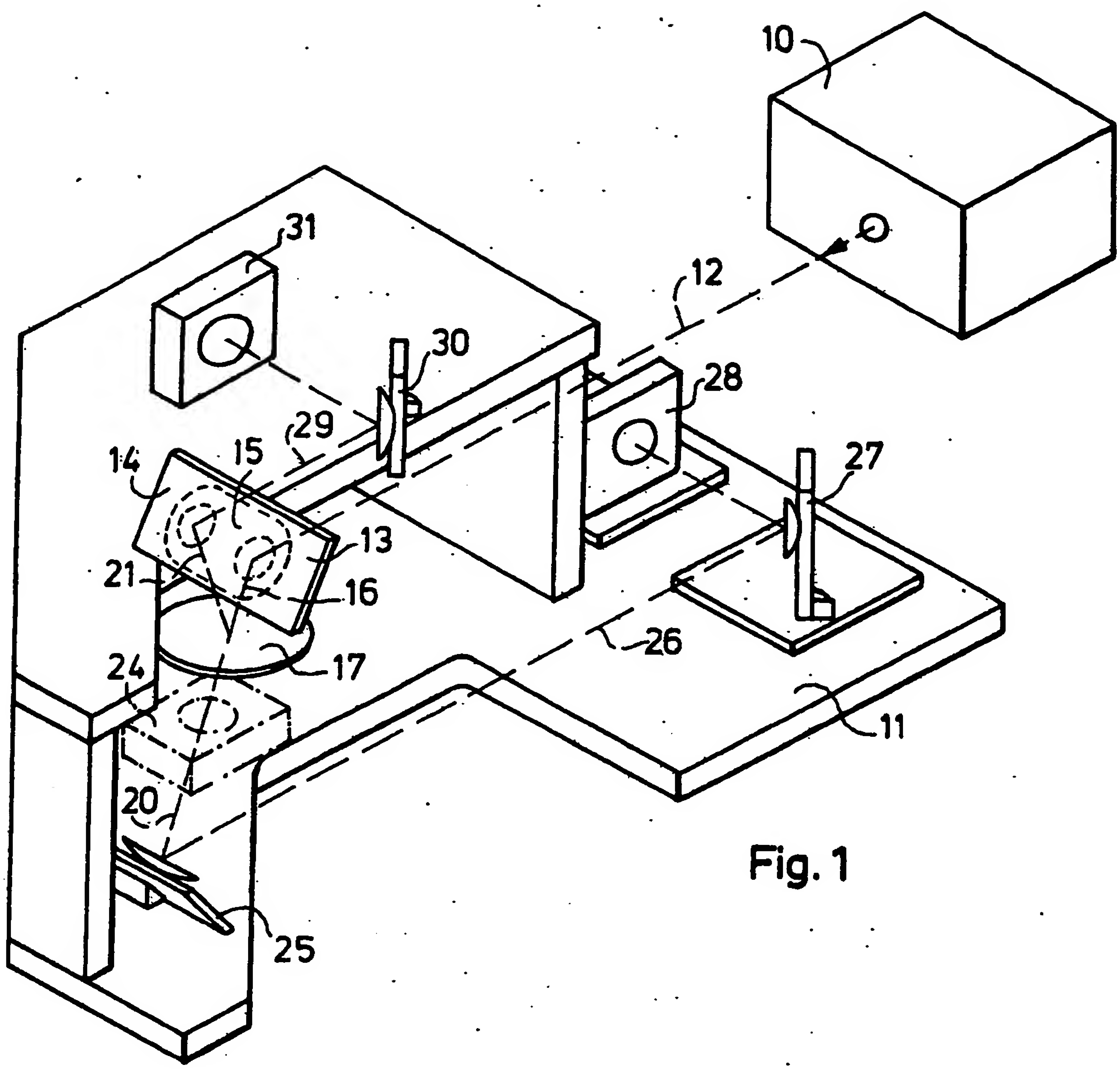

Fig. 1

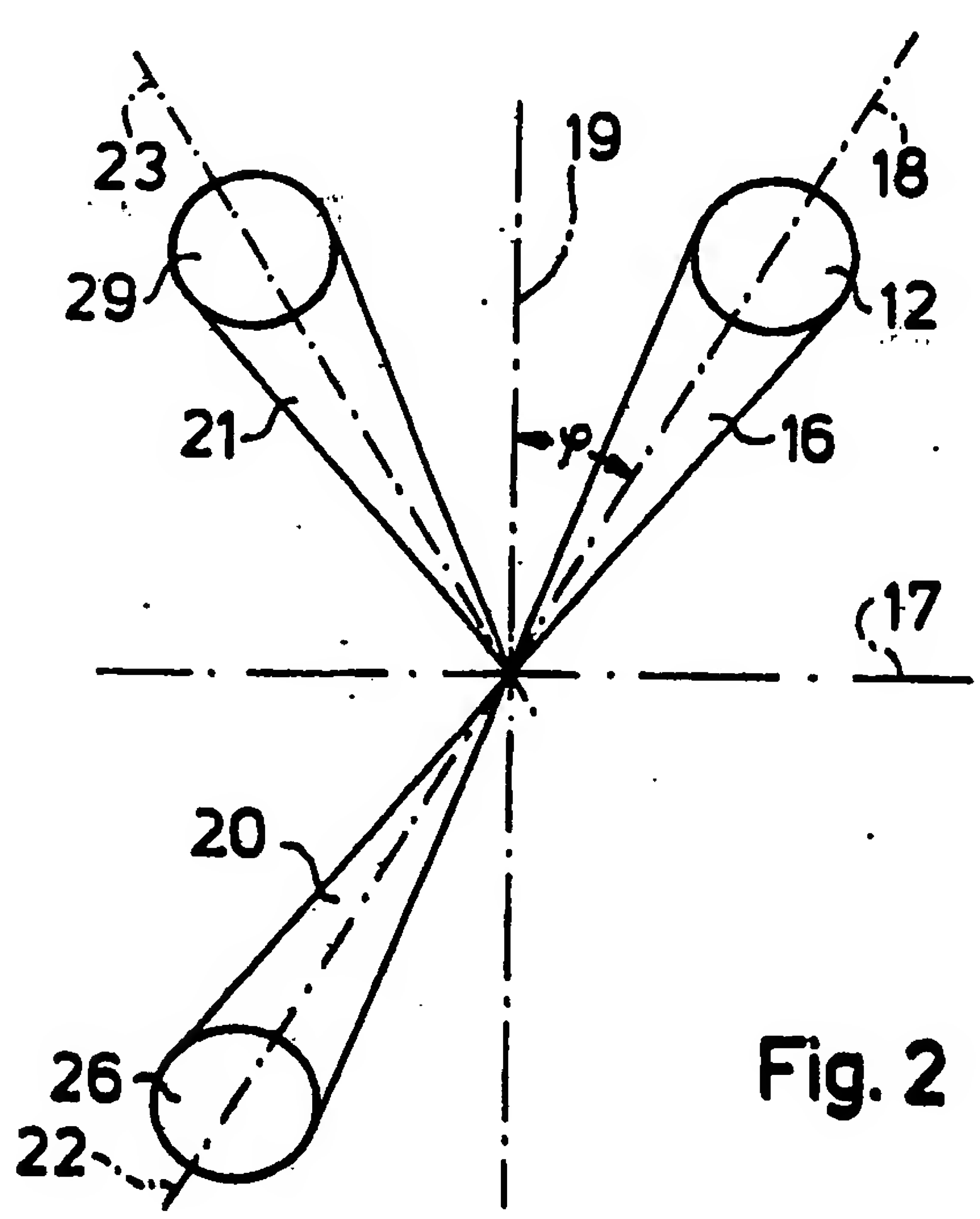

Fig. 2

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SPECIFICATION

Infrared spectrometer

The present invention relates to an infrared spectrometer comprising optical means for generating a beam of rays directed to a detector arrangement and focussing in a cross-sectional plane located within a straight section, and intended for receiving a sample to be investigated by transmission.

Known infrared spectrometers comprise a source of infrared radiation and a monochromator or double-gap interferometer for generating the measuring signal. For carrying out measurements on samples, two different methods have been known, e.g. the so-called transmission and reflexion methods.

For transmission measurements, the infrared spectrometer comprises optical means for focussing the rays emitted by the source of infrared radiation in a plane in which the sample to be investigated by transmission can be arranged using a sample holder. Usually, a parallel beam of rays is focussed by means of a parabolic mirror, the divergent beam of rays passing through the sample being again parallelized by other optical means and re-focussed upon an optical detector.

There are, however, many substances which are to be investigated by spectroscopy in the infrared domain, but which are impervious to infrared radiation. In such cases it has been known to utilize the infrared radiation retrieved from specular reflection and diffuse reflection by their surfaces. Such so-called reflection measurements have been described, for instance, on pages 1906 to 1910, Vol. 50 (1978) of the journal "Analytical Chemistry". The infrared spectrometer described in this publication is exclusively designed for carrying out reflection measurements.

Considering, however, that infrared measuring equipment is very complex from the technical point of view and very expensive, it has been suggested to provide such measuring equipment with direct radiation guide means to make the infrared spectrometer selectively suitable for transmission and reflection measurements when certain optical means are exchanged and certain conversion measures are carried out.

An attachment which permits such a conversion from transmission to reflection measurements is marketed, for instance, by Messrs. Harrick Scientific Corporation in Ossining, N.Y., USA. There has become known still another attachment of this type which is marketed by Messrs. Analect Instruments in Irvine, Ca., USA.

Although these known attachments do permit the use of the same radiation source and the same evaluation unit for the measuring results for both, transmission and reflection measurements, it is a disadvantage that quite extensive conversion work is required for converting the equipment from one measuring method to the other. During the time wh n this conversi n work is carried out, the infrared spectrometer cannot be used, and the working time of highly qualified personnel is tied up. In addition, the conversion from one measuring method to the other results in interruptions of quite considerable length, so that the performance of sequential measurements on short-life samples becomes impossible, or at least extremely difficult. Finally, the conversion of the optical unit results necessarily in changes of the ray path so that in the case of sequential measurements the sample to be investigated cannot be investigated at one and the same point, which is a very important drawback in particular in the case of inhomogeneous samples.

Now, it is the object of the present invention to provide an infrared spectrometer which permits transmission and reflection measurements to be carried out either simultaneously or sequentially, i.e. in direct succession, so that simultaneous or sequential measurements using the two measuring methods can be carried out on the same sample and at the same point of the sample.

According to the invention, this objective is achieved by an arrangement in which a second detector arrangement for receiving light reflected by a sample in a direction extending at an angle relative to the direction of the incoming light is provided on the same side of the cross-sectional plane upon which the beam of rays is directed.

Accordingly, the infrared spectrometer of the invention comprises two detector arrangements which are simultaneously operative and which provide the possibility to investigate light passing through the sample by means of the one detector arrangement, and light reflected by the sample by means of the other detector arrangement. In the case of samples which are partially pervious to light, the two investigations may even be carried out simultaneously. This extends considerably the application range of such a spectrometer.

Depending on the type of the sample to be investigated it may be appropriate to align the sample either vertically to a beam of rays passing through it, or at an angle relative to the incident and reflected beam, depending on whether the transmission method and/or the specular or diffuse reflection methods are to be used. To this end, the sample holder may be arranged in the area of the cross-sectional plane which permits the sample surface to be aligned vertically to the straight section of the beam of rays and/or vertically to the bisecting line of the angle formed between the directions of the incident and the reflected light.

Preferably, parallel beams of rays are produced in optical arrangement. Such a parallel beam of rays is concentrated by a parabolic mirror upon a focus in a sample surface. This permits on the ne hand a high radiation intensity and, on the other hand, the precise and best possible delimitation of the sample area to be investigated. For the purposes of evaluation of the transmission or r flection signal, the emitted divergent beams of rays are then re-parallelized and conveniently

focussed for incidence upon a detector. It is, however, also possible to supply the measuring signals to a detector arranged immediately behind the sample.

Considering that the ray paths of the incident and the reflected light are to be found in the same half space above the sample surface, a preferred improvement of the invention uses a common extra-axial paraboloid which focusses on the one hand the incident parallel beam of rays in the sample and parallelizes, on the other hand, the reflected divergent beams of rays. Due to this arrangement, very high optical precision is achieved and it is no longer necessary to adjust the ray paths separately.

Finally, very positive results are achieved by the infrared spectrometer of the invention by the fact that the sample is arranged in horizontal position. This eliminates certain disadvantages which may be produced in flat, vertically arranged samples under the effect of gravity.

In summary, the spectrometer of the invention is the first to provide the possibility to determine optical constants completely by simultaneous transmission and reflection measurements carried out at exactly the same point of a sample. This possibility is of particular advantage in the production of integrated circuits, for instance from silicium, where strict adherence to the production parameters is required. With the aid of the spectrometer of the invention, strict compliance with these production parameters and with the prescribed material properties can be guaranteed by simultaneous transmission and reflection measurements.

Other details and advantages of the invention will become apparent from the specification and the attached drawing.

The invention will now be described in detail with reference to the embodiment shown in the drawing in which

Fig. 1 is a perspective representation of one embodiment of the infrared spectrometer of the invention;

Fig. 2 is a diagrammatic representation of the ray path encountered at the sample in the spectrometer of Fig. 1.

In the embodiment shown in Fig. 1, a spectrometer unit 10 (monochrometer or interferometer) of the type usual in infrared spectrometers of the type concerned here can be seen. The optical arrangement, including the sample, is placed on a spectrometer table 11. The spectrometer unit 10 emits a parallel beam of rays 12 which impinges initially upon a first parabolic mirror 13. Preferably, the said first parabolic mirror 13 forms together with a fourth parabolic mirror 14 which will be described hereafter a common extra-axial parab loid 15.

The parallel beam of rays 12 is transformed in the first parabolic mirror 13 into an incident convergent beam of rays 16, as shown also in Fig. 2. The beam of rays 16 impinges upon a sample 17 arranged horizontally on a sampl holder which is not shown in the drawing for clarity's sake. As can be seen in Fig. 2, an angle φ is formed between the axis 18 of the incident beam of rays 16 and the vertical 19 drawn upon the surface of the sample 17.

The beam of rays 16 impinging upon the sample 17 produces on the one hand a divergent beam of rays 20 passing through the sample 17, whose axis coincides with the axis 18 of the incident beam of rays 16, and on the other hand a divergent beam of rays 21 reflected by the sample 17, whose axis 23 forms the same angle φ with the vertical 19, in the case of specular reflection of the light. It goes, however, without saying that an angle other than φ may be selected for the evaluation of diffused reflected light.

The spectrometer of the invention shown in Figs. 1 and 2 comprises first optical beam guide means and detectors for detecting the transmission signal, and further second optical beam guide means and detectors for detecting the reflection signal. The first set of these before-mentioned means may in a simple version of a spectrometer in accordance with the invention take the form of a first detector 24 arranged immediately below the sample 17 for receiving a divergent beam of rays 20 passing through the sample.

However, for carrying out exact measurements and achieving a higher signal density on the surface of the optical detector, a preferred improvement of the invention is equipped with a second parabolic mirror 25 for reparallelizing the beam of rays 20 so that a parallel beam of rays 26 is obtained which is then focussed upon a detector 28 by means of a third parabolic mirror 27.

At the same time, the reflected divergent beam of rays 21 is parallelized by the fourth parabolic mirror 14 mentioned before so that a parallel beam of rays 29 is obtained which is then focussed by a fifth parabolic mirror 30 upon a second detector 31.

It goes without saying that the detectors 24, 28, 31 shown in Fig. 1 are connected to conventional electronic evaluation means not shown in the drawing.

From the perspective representation of Fig. 1 it appears clearly that simultaneous transmission and reflection measurements can be carried out in this manner, without the need to make any conversions, as the ray paths of both, transmission and reflection, are encountered simultaneously and can be evaluated simultaneously. Accordingly, there is no need for changing the optical means or for moving the sample 17 to a different position, so that the sample 17 can be investigated by both measuring methods at exactly the same point.

It goes without saying that the optical ray guide means, in particular the mirrors 13, 14, 25, 27, 30 are meant to represent only one example of a ray path which seems particularly appropriate, but that other ray paths are of course also possible. The arrangement shown in Fig. 1 by way f example is particularly suited for

measurements performed on horizontally arranged samples 17 fixed in position only by the effect of gravity or vacuum. For measuring inclined or vertically arranged samples 17, the spectrometer table 11 could be tilted simply about the axis of the parallel beam of rays 12, or the ray path could be re-oriented appropriately in a conventional manner.

Claims

1. An infrared spectrometer comprising optical means for generating a beam of rays directed to a detector arrangement and focussing in a cross-sectional plane located within a straight section, and intended for receiving a sample to be investigated by transmission, wherein a second detector arrangement for receiving light reflected by a sample in a direction forming an angle with the direction of the incident light is arranged on the same side of the cross-sectional plane upon which the beam of rays is directed.

2. An infrared spectrometer in accordance with claim 1, wherein a sample holder may be arranged in the area of the cross-sectional plane which permits the sample surface to be aligned vertically to the straight section of the beam of rays and/or vertically to the bisecting line of the angle formed between the directions of the incident and the reflected light.

3. An infrared spectrometer in accordance with claim 1 or 2, wherein an incident beam of rays is focussed upon the surface of the sample by a parabolic mirror arranged at a distance to the surface of the sample.

4. An infrared spectrometer in accordance with any one of claims 1 to 3, wherein the beam of rays passing through the sample impinges directly upon a detector.

5. An infrared spectrometer in accordance with any one of claims 1 to 3, wherein the beam of rays passing through the sample impinged upon a second parabolic mirror for being parallelized thereby, and a third parabolic mirror focusses the parallelized beam of rays upon a detector.

6. An infrared spectrometer in accordance with any one of the preceding claims, wherein the divergent beam of rays reflected by the sample impinges upon a fourth parabolic mirror which parallizes the incident light and directs it upon a fifth parabolic mirror which in turn focusses the parallelized beam of rays upon a second optical detector.

7. An infrared spectrometer in accordance with claims 3 and 6, wherein the first parabolic mirror and the fourth parabolic mirror form a common unit, preferably an extra-axial paraboloid.

8. An infrared spectrometer in accordance with any one of the preceding claims, wherein the sample rests horizontally on a sample holder.

9. An infrared spectrometer substantially as herein described with reference to and as illustrated in the accompanying drawings.

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